Models Extracted from Text for System-Software Safety Analyses

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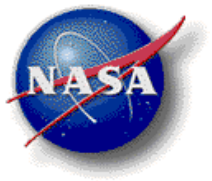
Abstract

This presentation describes extraction and integration of requirements information and safety information in visualizations to support early review of completeness, correctness, and consistency of lengthy and diverse system safety analyses. Software tools have been developed and extended to perform the following tasks: 1) extract model parts and safety information from text in interface requirements documents, failure modes and effects analyses and hazard reports; 2) map and integrate the information to develop system architecture models and visualizations for safety analysts; and 3) provide model output to support virtual system integration testing. This presentation illustrates the methods and products with a rocket motor initiation case.



Models Extracted from Text for System-Software Safety Analyses

Project:
Automated Tool and Method for System Safety Analysis

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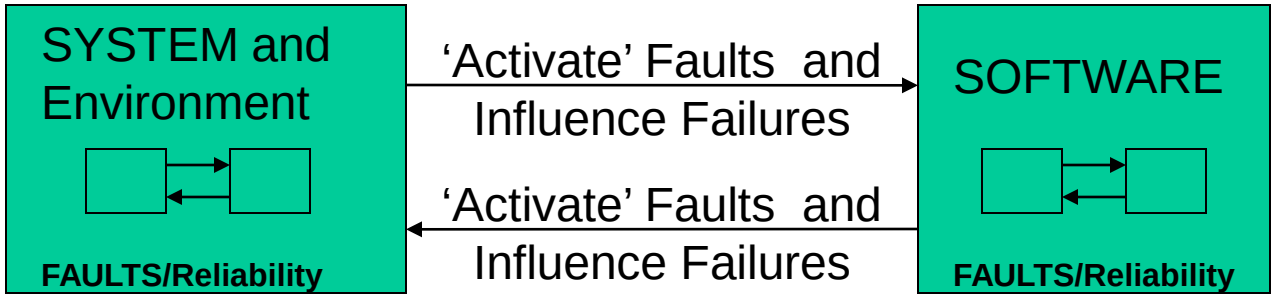
Essential Early Safety Reviews

- Requirements and design problems are the source of most operational software defects
  - System integration, interfaces, failures and hazard causes
- Analysis of information for Preliminary Design Review (PDR) is needed

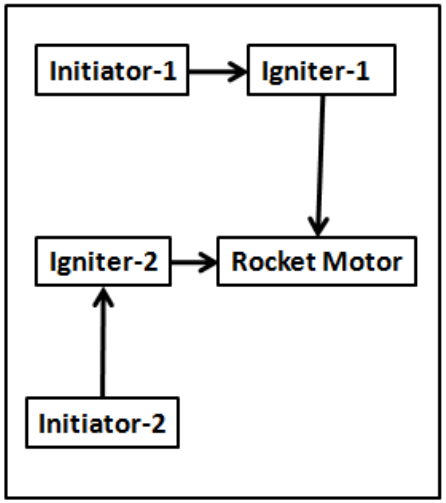


System Integration Operations and Stresses

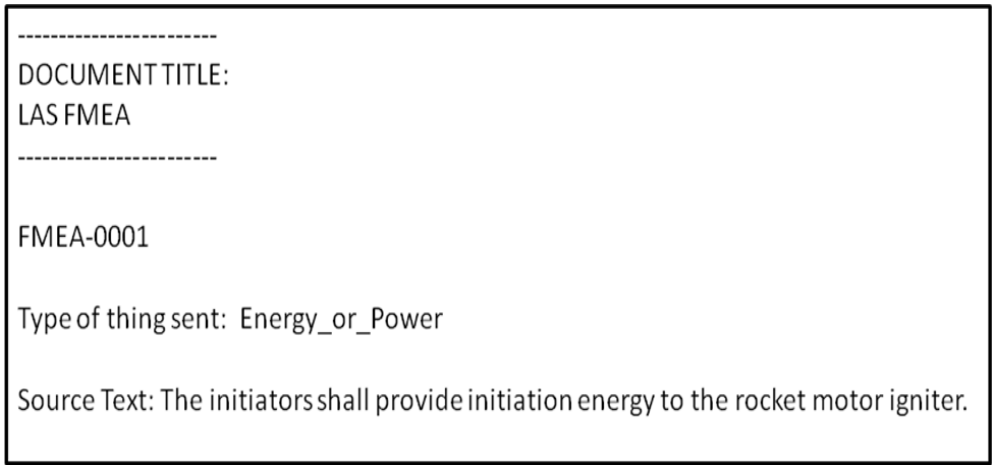
Integrated Review of Scattered Information

- Need: Efficient system safety reviews of large sets of contractor documents
  - Make short-fuse reviews of requirements, safety analyses and plans manageable
  - Integrate key information from diverse uncoordinated and evolving documents
    - Interface Requirements Documents (IRD)
    - Failure Modes and Effects Analysis (FMEA)
    - Hazard Reports (HR)
    - Fault Detection, Isolation and Response (FDIR)

Automated Modeling Solution



Model Graph



Connection Description Pop up from Arrow

- Models constructed from information extracted from text documents
- Visualizations for integrated insight into information scattered in large documents
- Output files and reports for model reuse in virtual testing and analysis for FDIR design

NASA Application Cases

- Constellation Program (CxP) CEV cases
  - Launch Abort System (LAS) with focus on Ordnance
  - Crew Module (CM)
  - Service Model (SM) Propulsion
- Useful in other aerospace projects where safety engineers perform early reviews of contractor products
  - FMEAs, Hazard Reports, safety requirements

NASA Automated Modeling Tools

- Semantic Text Analysis Tool (STAT)
  - Parsing and information extraction from text to XML
  - Multiple information types and document types
- Hazard Identification Tool (HIT)
  - Model construction and visualization
  - Component-connection models and visualizations
  - Analyses of redundancy, dependencies, linkages
- Output for further modeling and analysis
  - Information from FMEAs and Hazard Reports for FDIR
  - Virtual System Integration Lab (VSIL) simulator

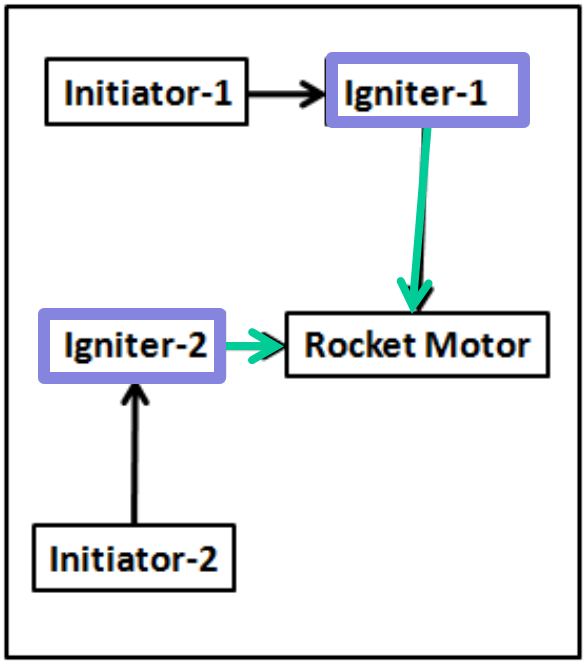
STAT Linguistic Text Extraction

- Powerful linguistic tagger and extractor
  - Advanced natural language processing
  - Extensive aerospace nomenclature
- Extractions for models

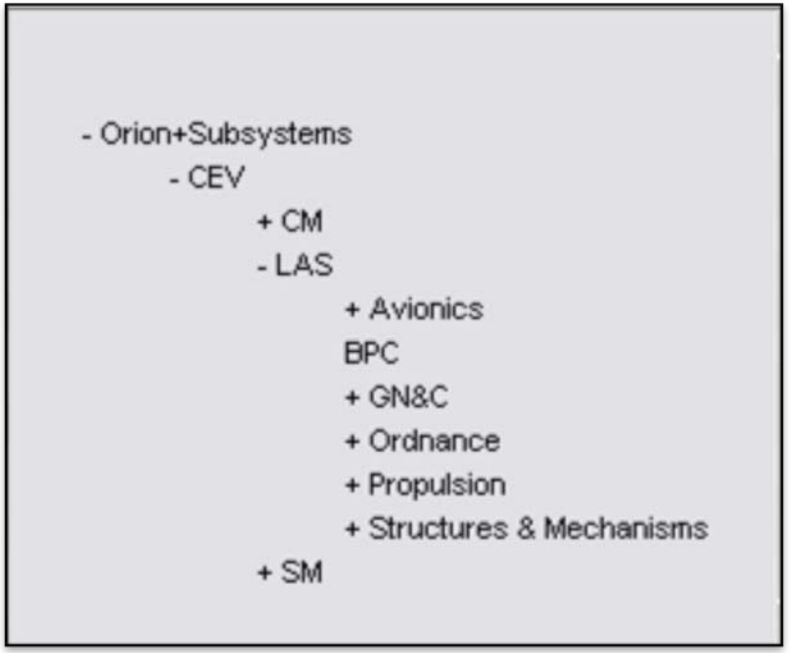
Document	Section	Model Information
FMEA	Front matter section	System hierarchy
	Worksheet hierarchy section	System hierarchy
	Worksheet: Item Function	Components, connections
	Worksheet: Failure modes and Causes	Failure mode descriptions
		Cause descriptions
Hazard Report	Cause Descriptions, Cause Control Descriptions	Component types
		Controls
IRD	Interface requirements	Components, connections
All Documents	Acronym Section	Acronyms
	Titles, identifiers	Traceability Information

HIT Automated Model Construction

Text extractions → Models → Visualizations → Analysis



Graph Display: **Redundant Components and Paths**



Tree Display: **Orion and Subsystems in Model**

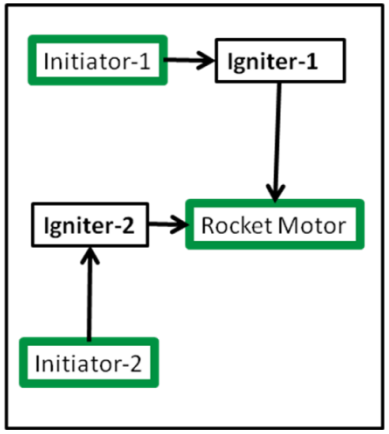
HIT Models for Review and Reuse

- Integrated review of multiple FMEAs
  - Completeness, duplication, consistency and redundant components and paths
  - Compare versions and re-analyze
  - Upstream and downstream dependency paths
- Review of FMEAs and Hazard Reports that are related to the same components
- Reuse of model information
  - Models and failure modes for simulation tests
  - Output information for fault analysis and FDIR design

Source Information Pop ups

- Click on components and connections to pop up FMEA and Hazard Report Information

Highlighting shows components with Hazard Report references



DOCUMENT TITLE:
LAS FMEA

Initiator – Igniter Connection

FMEA-0001

Type of thing sent: Energy_or_Power

Source Text: The initiators shall provide initiation energy to the rocket motor igniter.

DOCUMENT TITLE:
LAS FMEA

Initiators - FMEA

FMEA-00001

Item Function:
The initiators provide initiation energy to the rocket motor igniter.

Failure Mode 1
Criticality: 1
Failure of initiator

Hazard Report References for components of type **Initiator**

HR Number: LAS-FLT-00001
HR Title: Failure to Function Rocket Motor Results in Loss of Vehicle Control

Initiators – Hazard Report

Cause F: Igniter Failure
Cause Description …
Effect(s) …
Control(s)

Bullet: 1
Design. The igniter shall be designed to properly function upon receiving **initiator** stimulus.
Verification(s) …

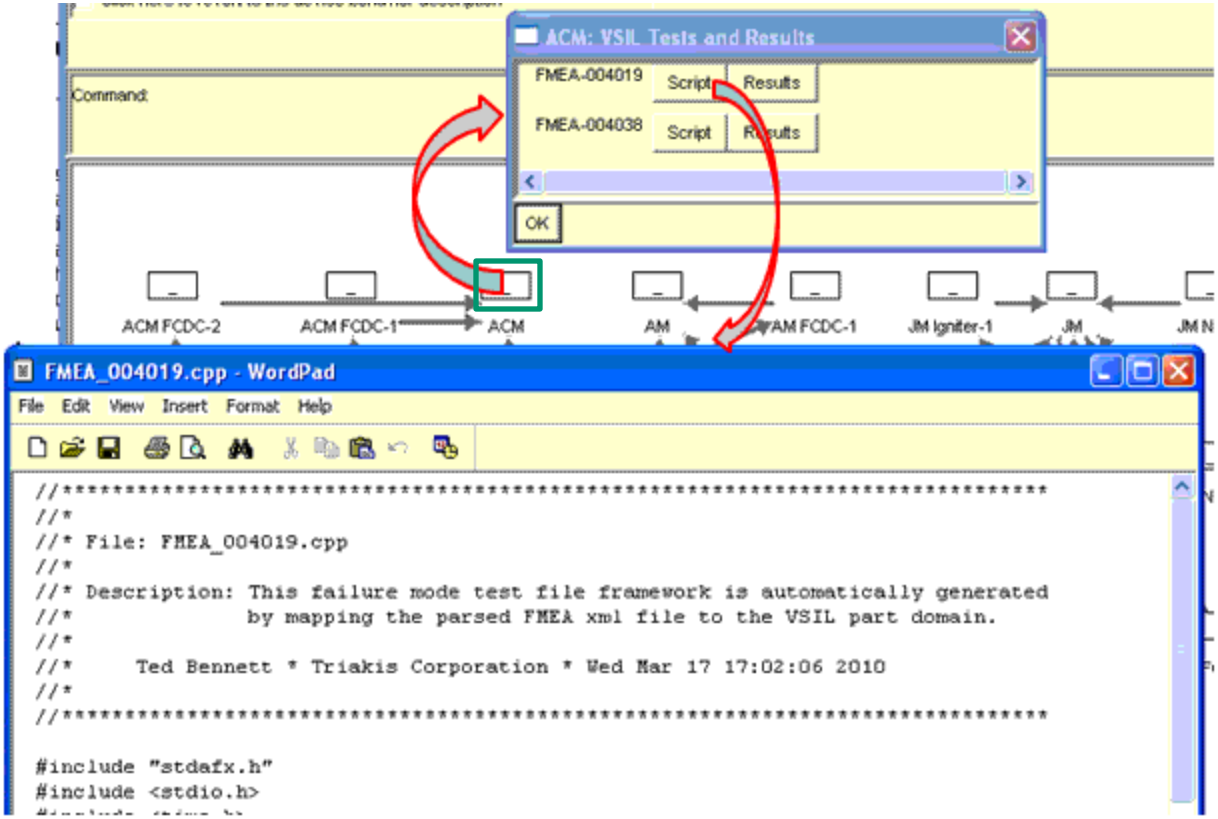
Cause G: Inadequate motor performance

Model Reuse for Design and Test

- Automated generation of fault analysis spreadsheets with HIT model information (from FMEAs and HRs)
  - Progress in extending CxP functional fault analysis (FFA) spreadsheets with Hazard Report information
- Triakis Virtual System Integration Lab simulator uses HIT FMEA Output to test flight software
  - Automatic translation of HIT FMEA output into failure mode test framework files
  - Failure mode tests verify integrated system and software
    - Manifest component failures and record software response
    - Monitor the state of any simulated part or signals between parts
  - HIT displays link back to VSIL test results and methods, for analysis and review

Links to Test Plans and Results

- Clicking on components brings up test plans and results.



Evaluations by Safety Engineers

- CEV avionics/software safety engineers – basis for a great leap in productivity of reviews
  - One-stop rapid integrated review
    - Thousands of documents for review were beyond human capabilities
    - Linking to specific information in the source documents makes the information easily accessible
  - Graph display makes key information stand out
    - Highlights missing or inconsistent information or terminology
    - Easy to see architecture and components that have no outputs or insufficient inputs, indicating omissions in design or documentation
    - Helps engineers check redundancy and review potential hazard paths
  - Engineers can trace from HRs to linked FMEAs, to find more detailed FMEA information for the HR
    - Essential but not possible before

Software Technology Maturity

- Technology Readiness Level 7: Prototypes that fully demonstrate operational and engineering feasibility
  - Prototype software with all key functionality should be available for demo and test
    - Distribution image and CEV models delivered to SMA on notebook computer
  - Prototype code should be relatively clean – ‘tis
  - Limited documentation should be available
    - User documentation and the Concept of Operations

NASA-owned Prototypes

- FY10 milestone: Tools on installation CD
  - Triakis COTS VSIL LAS simulator (C++) and documentation will be delivered separately
- STAT implemented in Perl and open-source LISP
  - Parsers: open-source Stanford and University of Central Florida
  - Aerospace nomenclature implemented in Protégé ontology
- HIT implemented in Allegro Common LISP

Recommended Next Steps

- Another Aerospace Case
  - Safety engineers can use these tools to significantly increase productivity of reviews
- Further evaluate feasibility of model reuse
  - Fault analysis and FDIR design spreadsheets
  - Virtual system integration testing for safety
- Develop software tool products based on existing Concept of Operations and prototypes
  - Develop according to NPR 7150.2
- Extend to assist developers of FMEAs and Hazard Reports, with evaluation and guidance

Summary: Models Extracted from Text

- Coordinated data and documents are desirable, but virtually impossible
- Integrated information for efficient safety review requires text extraction
  - Important information stands out
  - Details are a click away
- Information for follow-on design and test
  - Model for virtual safety testing
  - Information output for FDIR design